GST Responses to "Questions to Inform Development of the National Plan"

Name (optional): Dr. Darrel Williams

Position (optional): Chief Scientist, (240) 542-1106; darrel.williams@gst.com

Institution (optional): Global Science & Technology, Inc. Greenbelt, Maryland 20770

Global Science & Technology, Inc. (GST) is pleased to provide the following answers as a contribution towards OSTP's effort to develop a national plan for civil Earth observations. In our response we provide information to support three main themes:

1. ***There is strong science need for high temporal resolution of moderate spatial resolution satellite earth observation that can be achieved with cost effective, innovative new approaches.***
2. ***Operational programs need to be designed to obtain sustained climate data records. Continuity of Earth observations can be achieved through more efficient and economical means.***
3. ***We need programs to address the integration of remotely sensed data with in situ data.***

GST has carefully considered these important national Earth observation issues over the past few years and has submitted the following RFI responses:

- The USGS RFI on Landsat Data Continuity Concepts (April 2012),
- NASA's Sustainable Land Imaging Architecture RFI (September 2013), and
- This USGEO RFI (November 2013) relative to OSTP's efforts to develop a national plan for civil Earth observations.

In addition to the above RFI responses, GST led the development of a mature, fully compliant flight mission concept in response to NASA's Earth Venture-2 RFP in September 2011. Our capacity to address these critical national issues resides in GST's considerable bench strength in Earth science understanding (Drs. Darrel Williams, DeWayne Cecil, Samuel Goward, and Dixon Butler) and in NASA systems engineering and senior management oversight (Drs. Bryant Cramer and Dixon Butler) (Table 1). As a result, we believe that our response to the OSTP Request for Information is well informed and provides a major contribution to this national dialogue.

GST is a privately held, U.S. company highly competent and technically experienced in all areas of Earth science support, information systems and technology support, and program management. Within its primary NAICS code of 541712 (Research and Development in the Physical, Engineering, and Life Sciences), GST is a Small Disadvantaged Business.

Name	Affiliation	Expertise Relative to Civil Earth Observations RFI
Darrel Williams	GST Chief Scientist	• Landsat Project Scientist, 1992 – 2010 • Assistant Project Scientist, 1978 – 1984 • Catalyst behind TerEDyn mission concept development
DeWayne Cecil	GST Climate Data Record Program Manager	• 31-year federal sector career with NOAA, NASA, and the U.S. Geological Survey, focused on merging data from surface, atmosphere, and space-based systems to create consistent long-term records
Bryant Cramer	GST Board of Advisors, and Consultant	• Senior Manager of New Millennium Program Earth Observer-1 (NMP EO-1) • Deputy AA Earth Science at NASA HQ • USGS Director of Geography with oversight of all USGS remote sensing programs
Samuel Goward	U. of Maryland; GST Consultant	• Landsat 7 Science Team Leader • USGS Powell award winner • USGS/NASA Pecora award winner • PI on EV-2 TerEDyn proposal
Dixon Butler	GST Consultant	• Earth Observing System (EOS) Program Scientist, NASA HQ, 1982 – 1995 • Division Director, Earth Science Modeling, Data & Info Systems, 1989 – 1996 • Director, GLOBE program, 2002 – 2003 • Professional Staff, US House Appropriations Committee, 2003 – 2011

Table 1 – GST Offers Considerable Earth Science Understanding and NASA Flight Project Management Heritage

GST's ongoing activities specific to the nation's civil Earth observation programs involve significant support to both NASA and NOAA. For example,

- GST supports multiple organizations at the NASA Goddard Space Flight Center [e.g., Flight Projects Directorate (Code 400), Applied Engineering and Technology Directorate (Code 500), Sciences and Exploration Directorate (Code 600), and Information Technology and Communications Directorate (Code 700)].

- Relative to Earth science data downlink and capture from missions such as NPP and MODIS on EOS Terra and Aqua, GST plays a key role in developing technologies and operating protocols within Goddard's Direct Readout Laboratory.

- Oversight of the NOAA Climate Data Records Program Office in Asheville, NC.

- Prime contractor on NOAA's Comprehensive Large Array-data Stewardship System (CLASS) (i.e., big data).

- Provision of technical and engineering services within the Joint Polar Satellite System (JPSS) program office.

- GST received "Contractor of the Year" honors at NASA Goddard in 2003 and won Goddard's "Software of the Year" award in 2011.

Specific to this RFI response, GST offers considerable bench strength in Earth science understanding and mission planning and execution and in NASA systems engineering and senior management oversight (see summary in Table 1). For over three years, GST has led a group of experts that has been actively researching and developing a much lower cost, small satellite-based, moderate resolution, land imaging concept designed to acquire data consistent with Landsat missions in terms of acquisition geometry; areal coverage; spectral, spatial, and radiometric characteristics; and calibration so that the image data acquired will blend seamlessly with the baseline Landsat archive. The initial solution was fully articulated in the "Terrestrial Ecosystem Dynamics (TerEDyn)" flight mission concept proposal submitted to NASA in September 2011 in response to the Earth Venture-2 (EV-2) AO.

The TerEDyn concept (patent pending) is an innovative approach driven by a science requirements process (see **Attachment 1**, Section 5 "The Science Traceability Matrix") to acquire passive optical multispectral imagery (Landsat OLI bands 2 – 6, including SWIR1) using a push-broom sensor carried on a smallsat platform that has significant flight heritage and whose multiple uses leads to significantly lower costs. The TerEDyn imager is designed to image a 400 km swath yielding global land coverage after 7 days and to be operated in an "always on imaging when over sunlit land" mode. The combination of a greater than double swath width and much more robust imaging duty cycle would result in the capture of more than four times the areal coverage collected by any prior individual Landsat satellite. TerEDyn would support studies of vegetation dynamics and food security at an individual field scale via global collection of wall-to-wall 15 m VNIR and 30 m SWIR imagery. See **Attachment 1**, Section 4 "The Terrestrial Ecosystem Dynamics (TerEDyn) Mission Concept."

With regard to the 12 questions posed by OSTP through this RFI process, GST is pleased to provide the following answers:

1. **Are the 12 SBAs (**Societal Benefit Areas) **listed above sufficiently comprehensive?**

Answer: One of the major challenges for addressing Earth observations in the federal sector is the lack of a set of requirements for observations across all 12 Societal Benefit Areas (SBAs) so that similar requirements could be met through consolidated systems.

   a. **Should additional SBAs be considered?**

Answer: We suggest that it may be useful to revisit the SBA framework that is now nearly a decade old and has evolved as our understanding of these systems has advanced. Also, encouraging greater coordination between government organizations would lead to data sharing and meaningful cost avoidance. For example, you may consider encouraging coordination between, if not combining, the Climate and Weather SBAs since there should be no separation of observational requirements for Weather and Climate. For the past several years, GST has been supporting the NOAA in the area of climate analysis and, based on our experience, Operational Climate (OC) observations and measurements also satisfy the requirements for Operational Weather.

In terms of observations for the Weather and Climate SBAs, the 13-member agencies and departments of the U.S. Global Change Research Program (USGCRP) have stated they have separate mission requirements, budgets, and staffs that, in many cases, have overlapping requirements. Communication is limited to discussion of a set of priorities that put the agency or department's requirements ahead of national requirements (not established yet) for observations. The success of the USGCRP at its beginning was founded on giving priority within key agencies and OMB to the overall global change research mission rather than to the separate objectives of NASA, NSF, NOAA, and USGS. Based on the experience of our team, we can state that for decades it has been recognized in the research community that operationally collected data form a foundation for environmental understanding and that added attention to calibration and other steps that enable data to be quantitatively compared over time and space allow operational systems to collect data that meet the full research requirements at modest additional cost—costs far less that the parallel development of separate research missions.

For example, agency and department requirements for Weather and Climate observations are addressed by a plethora of regional and local weather, climate, and applications centers around the country (Table 2). Encouraging greater coordination among the 13 members of the USGCRP would lead to data sharing and meaningful cost reduction in an era of dwindling funding.

Weather and Climate Observations and Applications Offices/Centers	Agency/Department	Number of Centers, Offices, or Stations	Weather/Climate Observations
Climate Science Centers	Department of the Interior, U.S. Geological Survey	6	Yes
Landscape Conservation Cooperative	Department of the Interior, U.S. Fish and Wildlife Service	22	Yes
Regional Integrated Sciences and Assessment	NOAA	11	Yes
Regional Climate Centers	University based, NOAA funded	6	Yes
Weather Forecast Offices	NOAA	122	Yes
USDA Regional Climate Hubs	Department of Agriculture	8	Yes
NEON	National Science Foundation	20	Yes

Table 2 - Illustration of Similar Efforts

Superimposed on this plethora of centers, offices, and stations focused on observations, data generation, analysis, and application of Weather and Climate information are state and local observational stations and networks largely coordinated through the American Association of State Climatologists. We estimate that the cost to the nation of these observational networks is in excess of $2B per year. Observations include satellite, air-borne, and in-situ networks that are not targeted to a set of national requirements and, for the most part, are not coordinated across agencies and departments. The one exception to this is the NSF's National Ecological Observatory Network (NEON), which attempts to collect observations across several of the SBAs on a continental scale.

We suggest a comprehensive review of the observational requirements for all 13 of the agencies and departments that make up the USGCRP in terms of Weather and Climate. This review should include state, local (especially large metropolitan areas like New York City), and tribal representatives. With a set of national observational requirements for Weather and Climate as the guide for funding and spending, the missions and budgets of the 13 USGCRP members could be more effectively utilized and overlap could be avoided. The key objective is not to reduce the comprehensiveness and sampling density of environmental measurements and monitoring but to better integrate them into a set where observations that can easily be compared and integrated to provide insight at multiple scales ranging from local to national. One may view this as an environmental intelligence system that needs and would benefit from the same type of integration, interoperability, and data sharing as national security intelligence systems.

b. Should any SBA be eliminated?

Answer: No.

2. **Are there alternative methods for categorizing Earth observations that would help the U.S. Government routinely evaluate the sufficiency of Earth observation systems?**

Answer: The present method of categorizing Earth observations is adequate. The difficult task ahead is to determine which of these many observations must be sustained over long periods of time. Once the list of sustained observations is completed, they must then be prioritized and assigned to the civil agencies most interested in them. ***The sustained Earth observations should then be pursued through agency-based operational programs specifically designed to be affordable and dependable for gathering necessary observations.*** Consistent with the current Space Policy, NASA should build these missions, and the individual civil agencies assigned these sustained observations should operate them. All agencies should make use of the full set of data to fulfill their specific mandates.

3. **What management, procurement, development, and operational approaches should the U.S. Government employ to adequately support sustained observations for services, sustained observations for research, and experimental observations? What is the best ratio of support among these three areas?**

Answer: Our comments here apply best to space-based observations within the Weather, Climate, and Space Weather SBAs.

Three groups of observations are proposed based on how the observations are used:

1. Sustained observations supporting the delivery of services
2. Sustained observations supporting research
3. Experimental observations for research, technology innovation, or improved services

Of these three groups, the first two involve sustained observations that require that the same observation be made over long periods of time. In the case of climate research, this requires a continuous dataset spanning decades.

Sustained observations from space can be accomplished more efficiently through a family of similar missions organized into an operational program than by addressing the observation needs via a sequence of different experimental science missions.

Where experimental science missions address a specific set of scientific questions they should be selected and developed individually with separate single-mission budgets; they are unique and optimized to produce a specific research answer. Due to the complexity and risk of such missions, NASA usually assumes the role of the mission integrator. In the formulation of the Earth Observing System, NASA undertook a research mission with considerable operational aspects. This was done to address the needs of climate research that require sustained collection of intercomparable data on a comprehensive set of environmental variables. The mission has demonstrated its ability to meet many operational requirements; but the cancellation of the second and third copies of EOS satellites and instruments, rather than their transfer to operational use, led to the multi-year crisis in which the failure of any one satellite or instrument would have caused significant breaks in climate records and degradation of operational capabilities while replacements for Landsat and polar metsats experienced significant cost increases and delays.

Operational missions are funded as a group within a program with relatively steady annual funding. Multiple missions are purchased at the same time to drive unit costs downward, and they are built in tandem to minimize the size of the development workforce. Prime contracts are useful to reduce integration costs, and the federal government assumes a "light touch" oversight because the complexity and developmental risk is lower than with the experimental science mission. The recurring problem has been that the procurements of such systems occurs infrequently and the industrial infrastructure and knowledge to develop them is often lost in the interim leading to cost overruns and schedule delays that jeopardize the continuity of operational capability. More success in controlling costs has come from operational missions' use of a multi-mission ground system. Ground systems allow for the frequent insertion of new technology and capability; satellite missions do not. These differences are reflected in Table 3 below.

To address the challenge with satellite observations for research and operational delivery of services, we suggest that reliance be placed on systems using the smallest satellites and, therefore, less expensive satellites that will support the required observing instruments and that instruments be grouped only when their observations require tightly simultaneous acquisition to allow their data to be integrated into specific products. Systems should be based on ongoing development of a series of such smaller satellite missions so that redundancy is affordable and technology can be inserted periodically and continuity is maintained in the knowledge and capability to build them without having to relearn and cause cost overruns and schedule delays. Our TerEDyn approach illustrates this.

Experimental Science Missions versus Operational Missions for Sustained Observations					
	Funding	**Management**	**Procurement**	**Development**	**Operations**
Experimental observations for research, technology	Single mission	NASA as integrator	Single buys	Single build	Single ground system

innovation and improved services					
Sustained observations supporting research and the delivery of services	Steady program-level	Light touch/Prime contractor	Multiple buys of identical units	Tandem development to reduce workforce	Multi-mission operations center

Table 3 - Summary of Differences between Experimental Science Missions and Operational Missions Targeted at Obtaining Sustained Observations

Group 1) Sustained observations supporting the delivery of services: The National Weather Service is a good example of this group. This group of observations is generally produced by an operational program that provides sustained, dependable, timely, and affordable data and information that are incorporated into a variety of applications that support informed decision-making throughout the public and private sectors. The uses of these data and their associated applications are immediate, diverse, and immensely valuable to the U.S. economy.

Group 2) Sustained observations supporting research: The Landsat Program should be good example of this group, but it is not. Landsat should be an operational program, but NASA has developed it as a family of individual experimental science missions. From its origins in the 1960s, Landsat has been an orphan with no real federal home. More recently, the decision to fund Landsat within the EOS budget line and the policy approach based on NASA looking to other agencies to assume financial responsibility for development of operational satellite systems have continued to prevent its move to an operational service and research observatory. All of the Landsat missions taken together, however, represent a 42-year continuous record of land change throughout the world—a unique record of sustained observations. In this case, Landsat data are also associated with a number of applications that support a variety of land use and natural resource management services both in the U.S. and throughout the world. Trending and modeling studies dependent on long-term datasets are supported primarily by this second group of observations as well as many climate studies involving trends. Since this group involves sustained observations, it too should be structured as an operational program where the potentially lower costs of measurements would extend the research value of these programs.

Group 3) Experimental observations for research, technology innovation, or improved services: Most NASA science missions are examples of the third group of observations. For example, the Global Precipitation Measurement (GPM) mission that will launch in 2014 builds on the legacy of the Tropical Rainfall Measuring Mission (TRMM) to provide better assessments of global rain and snow through the use of a new Ka/Ku Dual-Frequency Precipitation Radar coupled with a multi-channel microwave imager. More importantly, it also serves as a reference standard for other precipitation missions to enable the pooling of their observations with those of GPM. In this manner, this unique new mission uses new technology to provide enhanced science and improved service by enabling the integration of rain and snow data from missions operated by international partners. However, there is almost certainly a need for such data to be collected indefinitely as part of monitoring precipitation globally on an operational basis.

<u>Ratio of support among and between Groups 1-3:</u> Group 3 missions are clearly the best funded, while Group 2 missions are the poorest funded. Group 3 missions with long lives on orbit (e.g., EOS) have attempted to support the sustained observations for research (Group 2) and occasionally have been adopted for Group efforts (e.g., land monitoring with AVHRR but containing undesirable artifacts). Group 1 missions, at least in support of the Weather Service, are reasonably funded, but the cost overruns and schedule delays have made this a challenge and constrained overall operational agency capabilities. Finding a procurement and development approach that recognizes the continuing nature of these observational systems would help control costs and improve reliability.

Within NPOESS, NOAA initially assumed that sustained climate observations could be included with weather observations. However, the climate sensors were subsequently de-manifested due to cost overruns, and NOAA has experienced great difficulty in finding a way to successfully manifest these sensors. More recently, NASA has been asked to include the "sustained observations for research" within their Group 3 missions.

What are desperately needed are true operational programs to support the missions that gather sustained observations for research. That there are observations that must be maintained over decades to support climate research is undeniable. Presently, Group 1 and Group 3 missions are trying to gather these observations on the margin. In Group 3 missions, new technology is generally employed to enhance instrument performance. However, in Group 2 missions, new technology should be employed to enhance efficiency and reliability to extend mission life and, thereby, lower the overall cost of the sustained measurements. Landsat would be an ideal pathfinder for defining how Group 2 missions should be developed and operated.

4. **How should the U.S. Government ensure the continuity of key Earth observations, and for which data streams (*e.g.*, weather forecasting, land surface change analysis, sea level monitoring, climate-change research)?**

Answer: ***The U.S. government should ensure the continuity of key sustained Earth observations, supporting both services and research by creating specific operational programs to gather these observations.*** Trying to gather these sustained observations marginally from Group 3 missions will never be entirely successful. Rather, the civil agencies most interested in these observations should accept the responsibility for operating these missions and sharing these data with the rest of the U.S. government. We believe that OSTP should facilitate the reallocation of funds between Groups 2 and 3 to better address those measurements that must be measured on a sustained basis. Current efforts to transition the Landsat program (beyond Landsat 8) from a Group 2 mission to Group 1 could serve as a prototype with respect to how best to address Group 2 missions. Furthermore, investing a small amount of money on missions that can demonstrate cost-effective, innovative new approaches that will reduce the overall cost of operational programs in the long run will help to ensure continuity of observations. Program features that should be sought to support continuity include:

- Use of smaller, more cost-effective satellite solutions

- Building and flying multiple small satellites rather than one big one
    - This approach also serves to minimize the risk of a crippling data gap
- Procurement and build of these satellites using commercial best practices
- Better coordination of mission solutions with the international community

5. **Are there scientific and technological advances that the U.S. Government should consider integrating into its portfolio of systems that will make Earth observations more efficient, accurate, or economical? If so, please elaborate.**

Answer: Yes, emerging scientific and technological systems exist that are dramatically less expensive but perform at a level that is comparable to today's operational sensors and systems. Specifically, we believe that there are now available to the federal government small satellite systems that can be procured at a fixed price and that can reduce operational and launch costs by as much as an order of magnitude.

Further, operational programs typically use standardization to reduce acquisition and operational costs. ***In developing operational programs, government-wide standards should be developed and implemented from the outset.*** Communication and data format standards are particularly valuable. Once a commitment has been made to an operational program to gather sustained observations, a committee representing the participating civil agencies should be established and initiate the definition of standards. Wherever practical, the government should adopt the use of standards that are broadly supported in commerce and industry as well as by other government systems. This should extend to the use of multi-application elements (e.g., satellite buses) for which there will be competitive pressures to help control costs.

6. **How can the U.S. Government improve the spatial and temporal resolution, sample density, and geographic coverage of its Earth observation networks with cost-effective, innovative new approaches?**

Answer: This question, although simply stated, is rather complex because there are a wide variety of missions that have features that are unique to the kind of phenomena being monitored from atmospheric temperature profiles to cyclonic patterns to forest and crop behavior. Each of the phenomena has its own unique characteristics that determine the spatial and temporal resolution, sample density, and geographic coverage needed. However, our response to the question will focus on the civilian Earth observing, moderate resolution remote sensing domain because of our insight and past experience in this area. Based on work we have pursued over the past four years, we believe that existing and emerging small satellite systems are now available that are able to improve operational capabilities in all four dimensions (spectral, spatial, radiometric, and temporal resolution) at significantly lower costs. Further, smallsat-based approaches are modular and adaptable, much less expensive than current missions, and permit insertion of emerging technologies as they mature. Equally important, an adaptation of dramatically lower cost solutions 1) will serve to remove an ongoing and very viable threat associated with crippling data gaps due to premature failure of singular flagship mission and, 2) are low enough in cost to allow multiple satellite to be inserted in orbit at a fraction of the cost of existing operational satellites.

GST's response to this question is based on a comprehensive Earth science understanding as well as considerable NASA flight project management and systems engineering heritage. This response is intended to provide insightful feedback and, in general, suggest a paradigm shift to lower cost, but technically sound, small satellite based solutions that are essential for improving temporal coverage compared with previous Earth observation missions. A historical perspective on the need for high repeat land imaging is presented in **Attachment 1**, Section 2.0 "Historical Recap of Pecora's Earth Observation Vision."

GST has been pursuing smallsat-based designs for the past several years that would serve as lower cost, low-risk alternatives to existing Earth observation designs. Emphasis has been placed on designs that are consistent with existing missions in terms of image geometry and radiometry to ensure continuity with existing archives, while dramatically increasing temporal repeat frequency and removing the threat of data gaps. Although we have placed particular emphasis on developing much lower cost approaches to acquiring a greater volume of Landsat-like passive, optical measurements globally, similar approaches can be applied to other types of Earth observation as well. See **Attachment 1**, Section 1 "GST's Experience with Smallsat Missions."

Programmatically, the government's approach to developing next generation Landsat systems has been to strive to improve the imaging performance of the prior mission under the assumption that more precise imaging would better meet national needs. However, this approach has two fundamental flaws: first, the mission is defined and driven by performance not requirements based on derived scientific needs; and, second, the costs to build Landsat 8-like imaging solutions has become so expensive that there is no hope of building more than one such system at a time on about a 10- to 15-year interval. Most importantly, since temporal resolution can only be met in the 20- to 30-meter range by having multiple satellites in orbit, the critical functionality of high repeat imaging can never be achieved. A detailed rationale supporting the need for high repeat imaging is presented in **Attachment 1**, Section 3 "The Impact of Cloud Cover on Earth Observation Success."

Given our experience and developed insight, we feel that the national interest will be better met by focusing on building lower cost land imaging missions that consist of a constellation of satellites that will be able to reduce the likelihood of crippling data gaps while improving imaging repeat cycle time. Based on today's commercial space capabilities, small satellites can be built with stable output that can be calibrated to levels commensurate with the performance of the highly regarded Landsat 5 TM and Landsat 7 ETM+ imagers. Further, small satellite-based, lower cost solutions will translate to a sustainable program consisting of multiple spacecraft in orbit at the same time, thereby transforming what USGS and NASA will be able to offer to the user community (i.e., dramatically enhanced imaging frequency at Landsat spatial and spectral resolution).

As Surrey has demonstrated via the impressive evolution of their DMC MSI imagers (costing < $1M each), consistent, stable imaging can be accomplished at much lower cost than existing Landsat 8 OLI-like solutions. USDA has found the dramatic augmentation in temporal coverage offered by DMC imagers to be very useful in generating highly accurate products like CropScape (http://nassgeodata.gmu.edu/CropScape/). USDA is getting classification results comparable to those derived from Landsat imagery by being able to assess crop conditions more frequently throughout the growing season due to the increased availability of temporal repeat from those satellites.

A critical emerging issue is the cost realism of smallsat missions. Recently, Aerospace Corporation conducted a study on the true cost of Surrey Smallsat Satellite Systems. The study findings are contained in Aerospace Report # ATR-2012 (5708)-1, "The Surrey Satellite Technology Cost Study Results," dated March 23, 2012, and authored by Robert E. Bitten, Debra L. Emmons, and David A. Bearden at the NASA Programs Division, Civil and Commercial Operations. This report vetted Surrey costs and heritage using standard, updated Aerospace Corporation practices and models.

A key point to consider when reviewing our response is that the GST team has unique experience in being able to offer low cost, low risk solutions to the requests in the RFI. In providing this response, the science goals articulated in NASA's SSE Roadmap 2010 Carbon Cycle and Ecosystem report were considered and a Science Traceability Matrix (STM) formulated what we believe can be used to drive and validate the development of an end-to-end solution based on fundamental science principals and objectives. See **Attachment 1**, Section 5 "The Science Traceability Matrix."

Recognize that long-term space observations will need to be complemented by an increased set of ground-based observing networks such as NEON and take advantage of the development of such systems for research to pioneer their development for operational measurements and monitoring as has been done with the satellite research missions.

7. **Are there management or organizational improvements that the U.S. Government should consider that will make Earth observation more efficient or economical?**

Answer: Provide a mechanism whereby budget trades for providing the environmental observing and supporting information systems are made on a civil government-wide basis as was done for the USGCRP at its inception. Coordinate this with the Appropriations Committees of the Congress so that this approach is effectively implemented through funding legislation.

Additionally, Earth observation systems should be designed to enable fixed price contracting rather than a "cost plus" approach to contracts. This is fundamental to executing an operational program. Though the U.S. government has not historically taken this approach, it has been proven successful internationally and commercially. Most of the recent successful commercial space operations, such as the Surrey DMC systems, use fixed price contacts.

8. **Can advances in information and data management technologies enable coordinated observing and the integration of observations from multiple U.S. Government Earth observation platforms?**

Answer: This is already being done in some cases (e.g., operational weather). The available technology can be employed to extend this to more systems, including those outside the federal government such as state and local governments and citizen science systems.

9. **What policies and procedures should the U.S. Government consider to ensure that its Earth observation data and information products are fully discoverable, accessible, and useable?**

Answer: Continue to provide the data at no charge. For example, since adopting a no-cost model for all Landsat data acquired from the USGS EROS Center in late 2008, the daily rate of scene downloads now exceeds the highest annual rate of downloads when EROS was operated under a partial cost recovery model. This no-cost access to observations is a strong stimulus to practical applications and advances research with the acquired observation sets.

10. **Are there policies or technological advances that the U.S. Government should consider to enhance access to Earth observation data while also reducing management redundancies across Federal agencies?**

Answer: Better interagency coordination would result in cost savings. You must put somebody in charge that can affect the budgets of the participating agencies. The agencies are traditionally more inclined to compete then to cooperate and real leadership is required to make the shift.

11. **What types of public-private partnerships should the U.S. Government consider to address current gaps in Earth observation data coverage and enhance the full and open exchange of Earth observation data for national and global applications?**

Answer: The U.S. government should set an example by providing free data as is presently done with Landsat. Moreover, the U.S. government should encourage international partnering in space as represented by the Committee on Earth Observation Satellites (CEOS), as a single example.

12. **What types of interagency and international agreements can and should be pursued for these same purposes?**

Answer: Space agencies all over the world look to NASA, NOAA, and the USGS to lead in developing international cooperation in space. The OSTP should facilitate the funding to these agencies to capitalize on this opportunity. Practically coordinating our space investments on a worldwide basis yields enormous dividends in addressing the scientific research associated with weather and climate. Scientifically, we move farther and faster with greater cooperation.